Identifying Inertial Modes in a Hide-Titman Flow

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Background

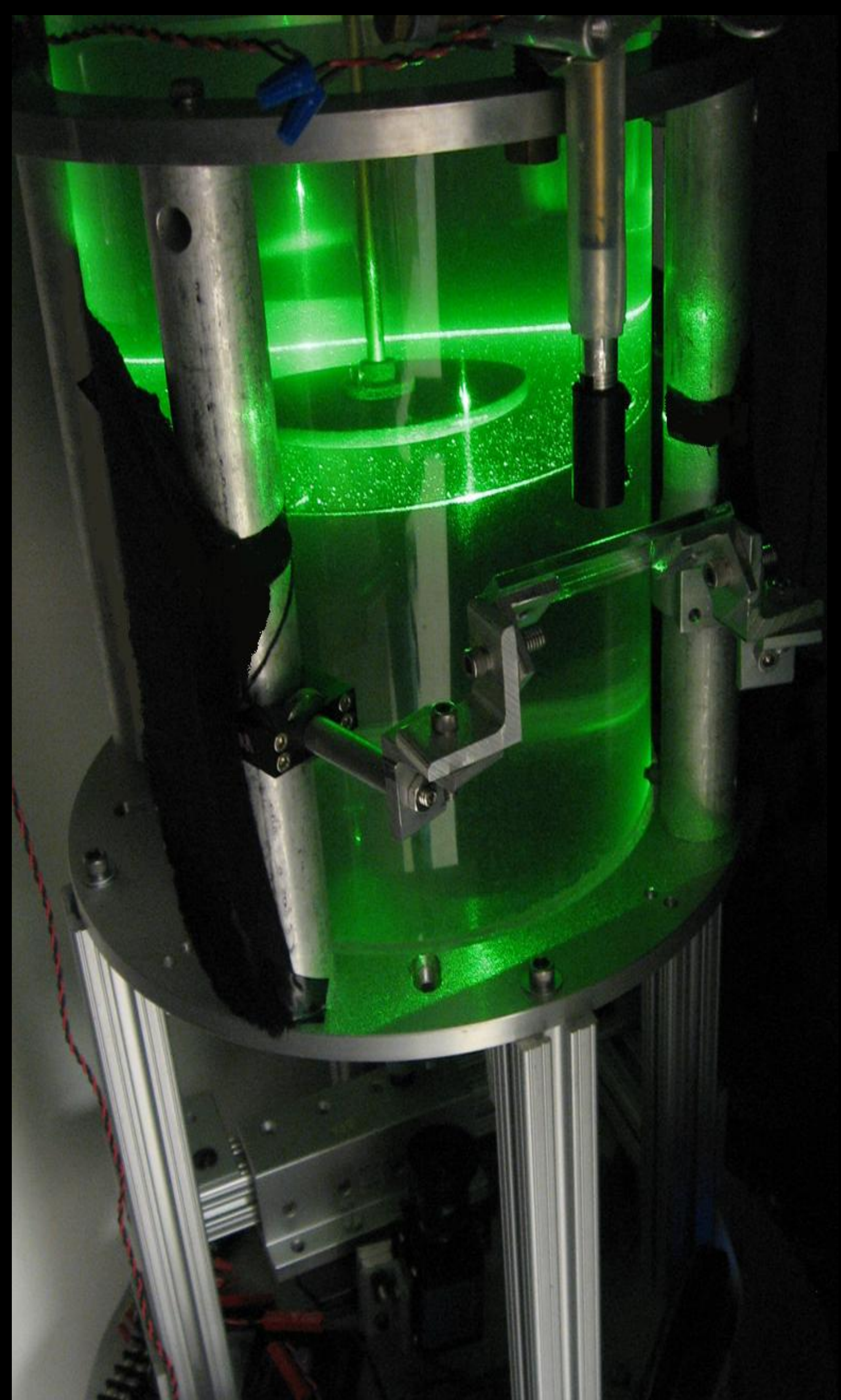
- Hide and Titman (1967)[1] studied fluid flow subject to differential rotation between a cylindrical container and a thin disk mounted coaxially within it
- Zhang *et al*. (2000)[2] formulated analytical solutions to the Navier-Stokes equations to model inertial waves in a cylindrical annulus
- Kelley *et al*. (2007)[3] postulated that differential rotation drives inertial modes

Question

Will low frequency waves in a Hide-Titman flow match specific inertial modes predicted by Zhang?

Apparatus

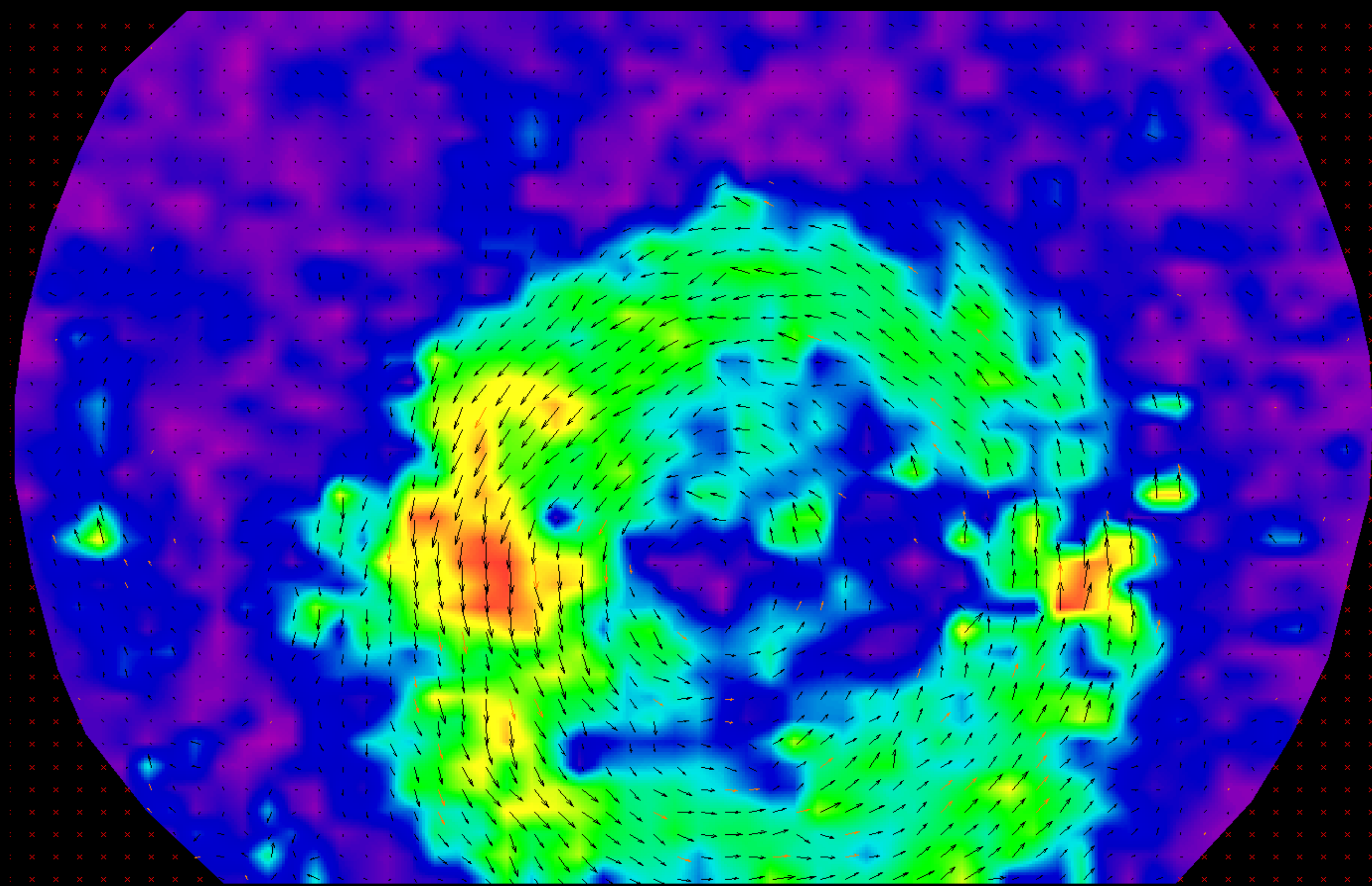
- Clear acrylic cylinder was mounted on a rotating table
- Thin disk suspended on a coaxially shaft
- Laser sheet projected parallel with the top and bottom of the cylinder
- Camera mounted below on rotating table
- Upper and lower motors to power differential rotation



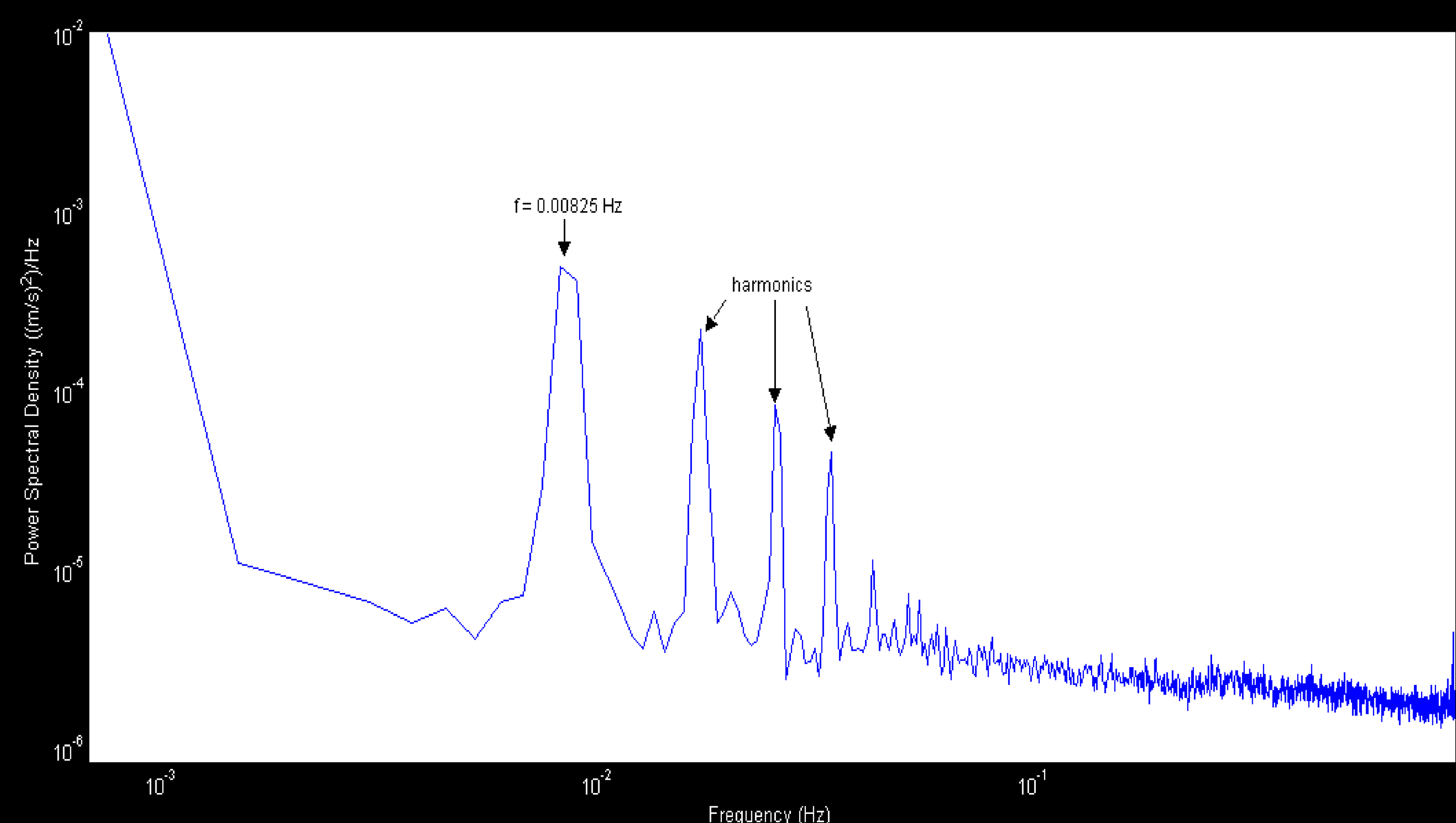
Particle Image Velocimetry

Particle Image Velocimetry (PIV) software tracks a specified square of pixels in each frame and provides a velocity vector for that region through time. Long exposure data best reduces noise.

Observations

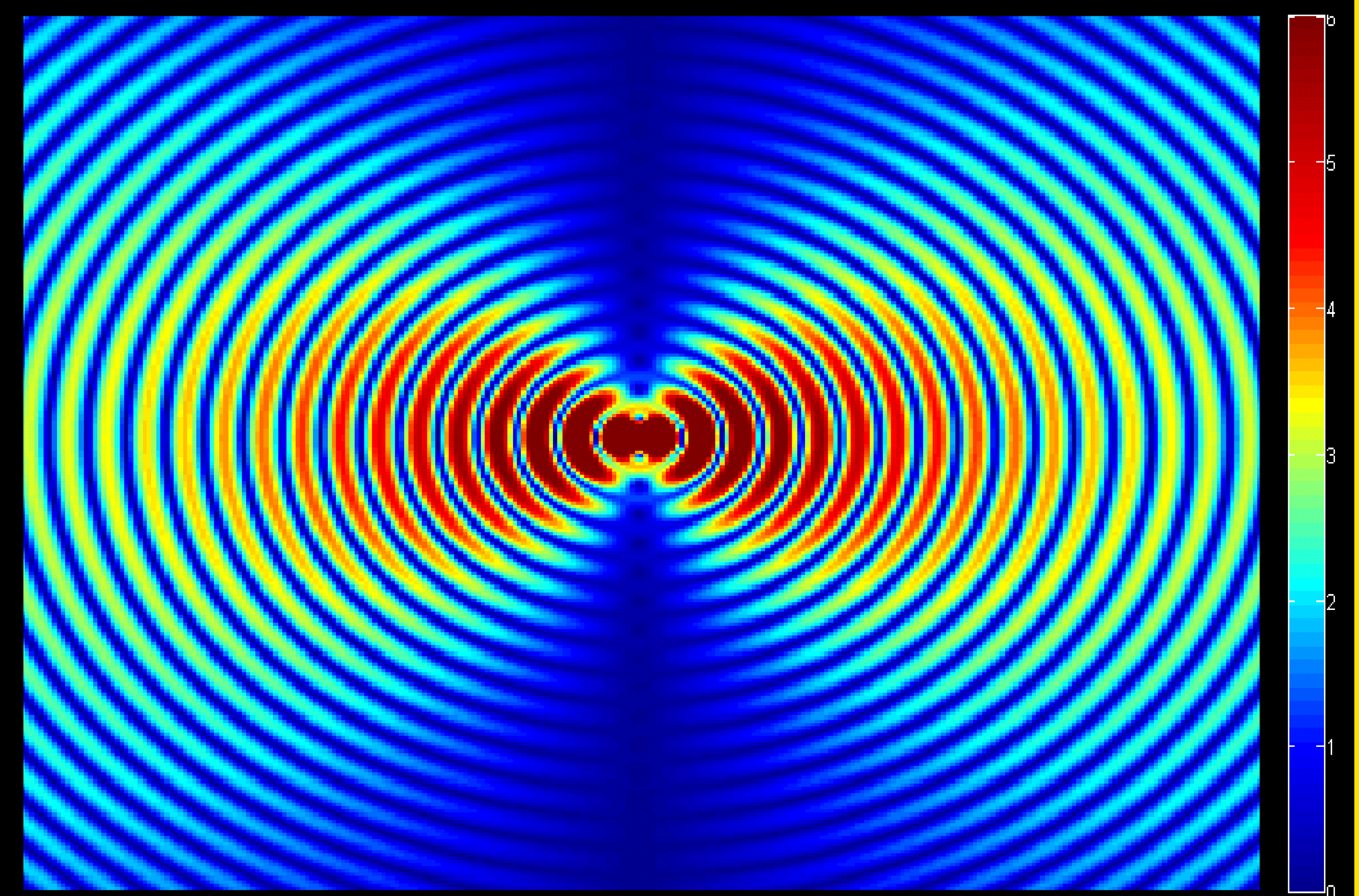


Velocity vectors and magnitude for one video frame of Ro= -0.5, laser sheet 4.75in from bottom

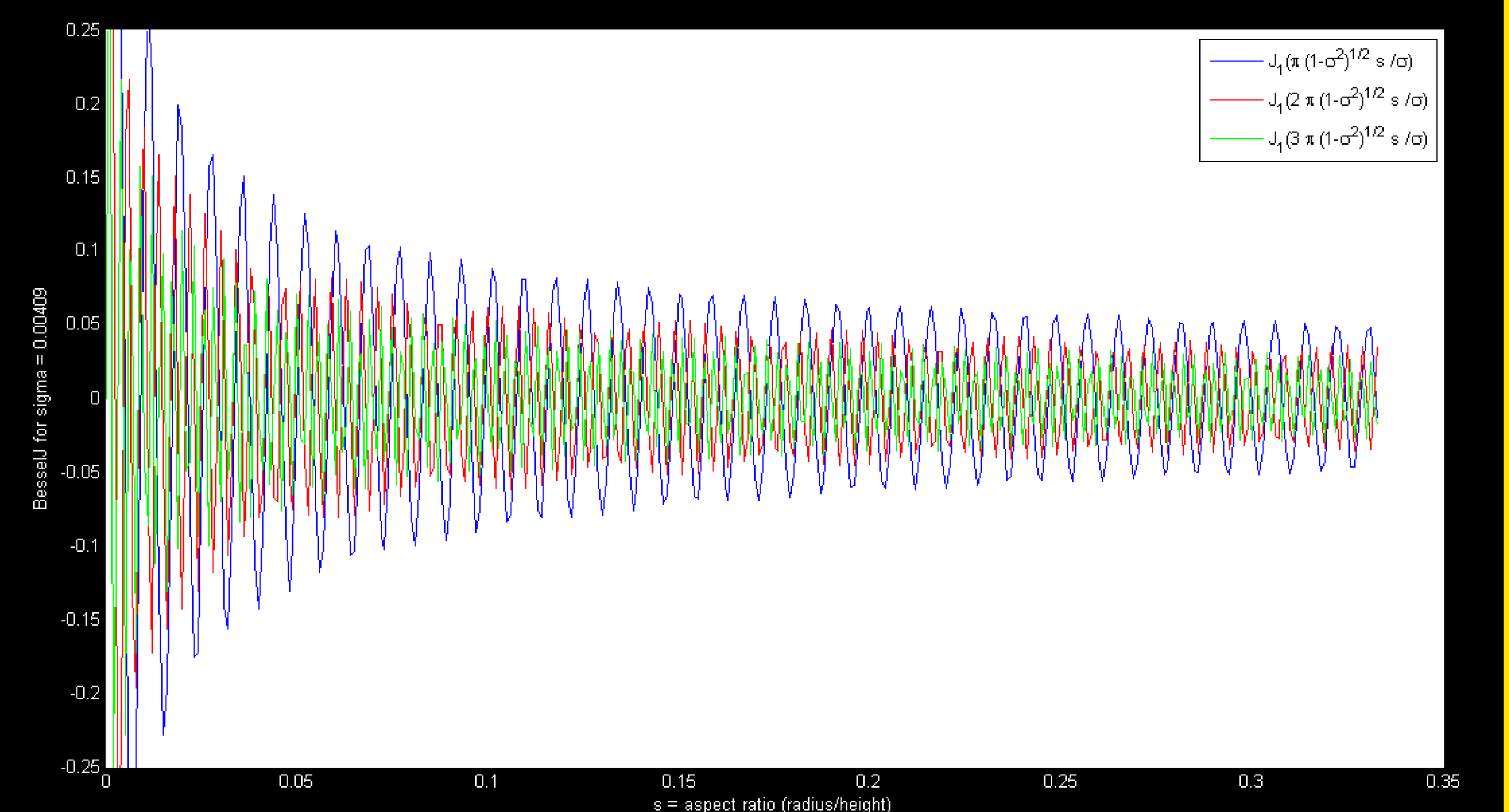


For Ro= -0.5, the most powerful modes over 45 minutes of data had a frequency of 0.00825 Hz.

Theoretical Models



Theoretical predictions of velocity magnitudes for an inertial mode of frequency 0.00825 Hz.



The complex theoretical field arises from Bessel functions which oscillate radially for all low frequencies

Conclusion

The stark contrast between the observed fields and the theoretical model indicates that low frequency waves in this geometry do not correspond to one unique inertial mode.

Sources: **1)** Hide, Titman. "Detached Shear Layers in a Rotating Fluid". Journal of Fluid Mechanics 29, pp39-60 (1967). **2)** Zhang et al. "On Inertial Waves in a Rotating Fluid Sphere". Journal of Fluid Mechanics 437, pp103-119 (2000). **3)** Kelley et al. "Inertial Waves Driven by Differential Rotation in a Planetary Geometry". Geophysical and Astrophysical Fluid Dynamics 101, pp469-487 (2007).